The irradiation damage to cement-based composites in the gamma radiation field occurs only after exceeding the limit of the absorbed dose of about $2 \cdot 10^5$ kGy. At that point, a substantial decrease in the mechanical properties of composite is observed. Below the critical dose the main cement hydrates are considered not susceptible to gamma irradiation damage. Therefore, the stability of the physical and mechanical properties of the material is assumed in the range of moderate absorbed doses (up to 20 MGy) in the field of gamma radiation. However, this assumption may be incorrect if internal swelling reactions, such as alkali-silica reaction (ASR), are triggered by gamma or temperature environmental exposure. The kinetics of the alkali-silica reaction under gamma radiation and elevated temperature have not been extensively studied, regardless of the radiation dose. To properly describe changes in thermoelastic properties and volume stability of cement composites with moderately reactive aggregates, a better understanding of the issue and experimental identification of computational model parameters is needed.

The aim of the Project is to assess the volume stability and thermoelastic properties of composite materials with cement matrices and to identify models for predicting their behavior under temperature and gamma irradiation. The research program will involve advanced characterization of cement-based composites before and after exposure to gamma radiation or temperature. This includes selecting constituent materials, developing a methodology for exposing composites to gamma radiation, characterizing volume changes and thermoelastic properties, and implementing the determined properties in computational models of material degradation phenomena.

The constituent materials of composites will be selected to provide conditions for ASR occurrence. The chemical composition of the materials (cement, aggregate, and modifiers) will be determined, and aggregates with high SiO_2 content and cements with high leachable alkali content will be selected. The susceptibility of aggregates to ASR will be evaluated by determining their mineralogical composition and identifying reactive minerals, i.e. micro- and cryptocrystalline quartz, strained quartz, chalcedony and volcanic glass. The potential of selected aggregates and additives for controlling the kinetics of the alkali-silica reaction will be determined based on observations of volumetric changes in cementitious matrix composite materials exposed to an alkaline environment and elevated temperature.

A methodology for exposing cementitious matrix materials to gamma radiation while maintaining a highly alkaline environment will be developed. A sample capsule will be designed, and a gamma radiation source will be selected. Preliminary laboratory tests will be conducted to confirm the feasibility of determining selected thermoelastic properties on samples adapted to the conditions of the gamma radiation source. The process of sample preparation, safe shipping, storage, and measurement during exposure to gamma radiation will be carefully planned.

The effect of variation in mineral composition and relative content of constituents, as well as the effect of selected exposure conditions, on the kinetics of degradation processes due to the alkali-silica reaction will be analyzed. Specimens prepared using the selected materials will be exposed to gamma radiation or elevated temperature in an alkaline medium. The kinetics of degradation processes will be measured by recording the change in dimensions of the composite samples over time. The effects of varying radiation dose and different temperatures on the kinetics of damage phenomena will be analyzed. The durability of the composite in high pH environments will be evaluated by examining changes in selected thermoelastic properties such as coefficient of thermal expansion, microhardness, elastic modulus, and porosity. Analyzing the changes in thermoelastic properties will provide a better understanding of the consequences of volume changes in composites due to ASR.

The data acquired from experimental testing of cement matrix composites will allow the determination of computational model parameters depending on the material composition, which will enable the modeling of internal swelling phenomena and prediction of properties over time as a function of absorbed dose.

The significance of Project's topic is related to a present-day and future energy source developments. The pivotal role of material behavior in the unique radiation environment makes the materials engineering a subject of paramount importance in the future of nuclear energy in the world. With a properly modest perspective, distinguishing the role of materials close to the reactor core and materials affected by much less intensive radiation fields, the objectives of this Project are complementary to the broader understanding of radiation and temperature effects in structural materials.